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SIMPLIFIED 12 GHz LOW NOISE CONVERTER WITH MOUNTED PLANAR CIRCUIT IN THE WAVEGUIDE

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SIMPLIFIED 12 GHz LOW NOISE CONVERTER WITH MOUNTED PLANAR CIRCUIT IN THE WAVEGUIDE

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1. Introduction

There is a demand for the development of low-noise converters with a high sensitivity and low cost for satellite broadcasting and ground broadcasting in the 12 GHz band. /1**

The simplified 12 GHz low-noise converter with mounted planar circuit in its waveguide which is reported here meets these purposes. It is a converter of an entirely new type.

The prototype converter was tested with a signal frequency of 12 GHz and an intermediate frequency of 420 MHz, and success was achieved in obtaining results of an actual conversion loss of 3.5 dB or less and a combined noise figure of 4.5 dB (with a noise factor of 2.0 dB for the intermediate frequency amplifier).

In the following sections, let us describe the composition of this circuit and the results of trial manufacture of the prototype.

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2. 12 GHz Converter Using Mounted Planar Circuit in Waveguide

The converter with a high sensitivity and low cost must have a simple construction and must be capable of mass production. Therefore, we made special efforts to lower the cost by using the mounted planar circuit which we had proposed in [1, 2]. The composition of the circuit described here is one in which all the necessary circuit elements are formed by blanking or etching on a single metal plate, and this metal plate is inserted into the waveguide. Consequently, the greatest advantage of this circuit is the fact that all the circuits necessary for the converter can be formed on a single metal plate, that is, on a single plane. As a result, mass production becomes possible. Furthermore, the waveguide itself can be split into two segments when it is being assembled in place. Therefore, it is possible to adopt the molding or bending methods, which are simpler than the drawing method of molding used in the past. It is also possible to use waveguides made of plastic. In the following sections, let us describe the parts of the converter. In this report, we deal with the results of a trial manufacture of the prototype converter as an application of the mounted planar circuit.

A pattern of the mounted planar circuit used in the prototype converter is shown in Figure 1. This pattern, from left to right in Figure 1, consists of a signal frequency pass filter, the Schottky diode mounting, the local oscillation frequency pass filter, and the mounting part for the local oscillation gun diode. A copper plate with a thickness of 0.3 - 0.5 mm is suitable for this pattern. If the pattern is formed by etching, it is possible to use a plate with a thickness of as little as 0.3 mm from the standpoint of dimensional precision. If it is /2

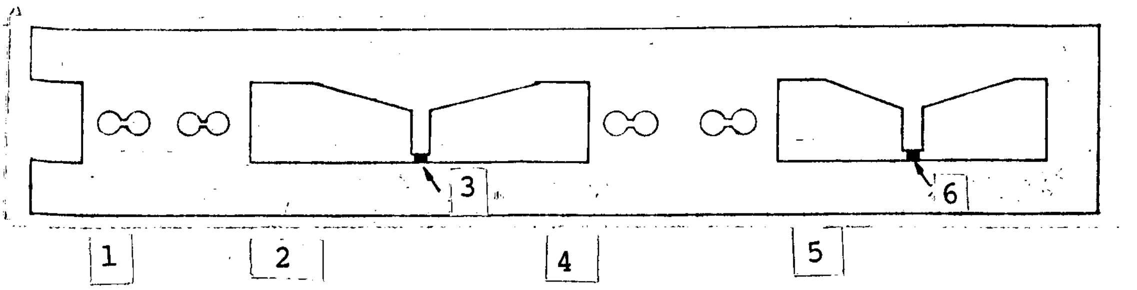


Figure 1. 12 HGz down converter with mounted planar circuit:

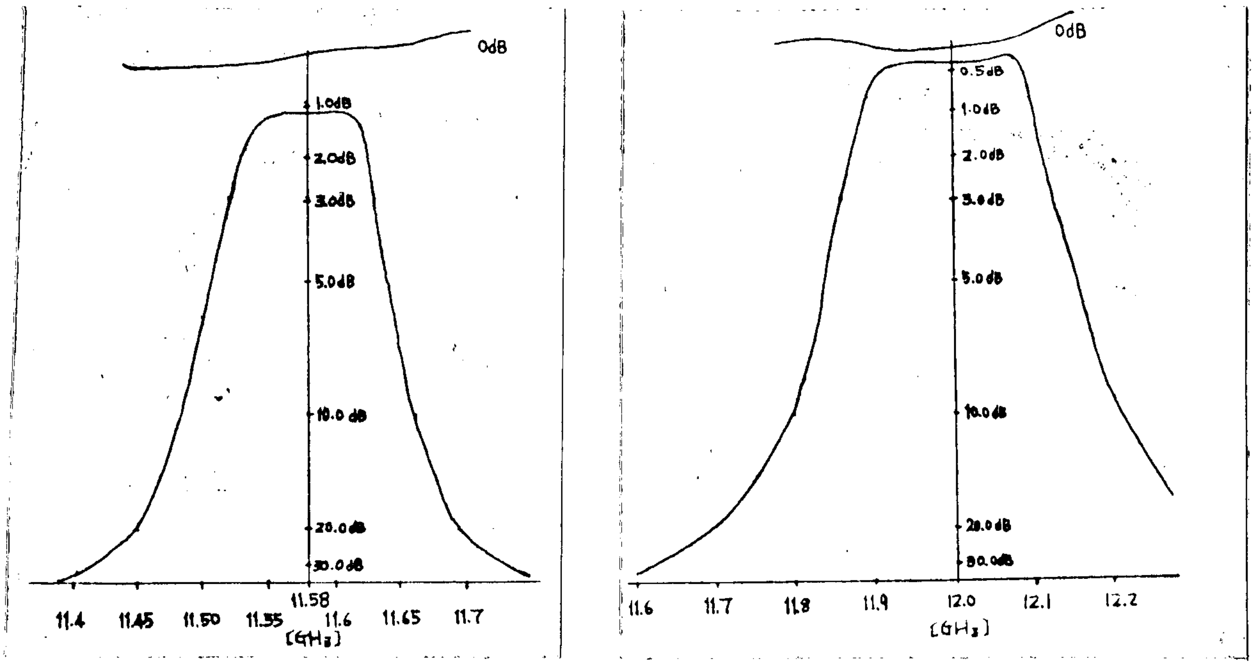
1 — signal pass filter; 2 — diode mounting; 3 — Schottky diode; 4 — local oscillation pass filter; 5 — local oscillation circuit; 6 — gun diode

formed by blanking, it is possible to attain a precision of 20 μ or less when, for example, a copper plate with a thickness of 0.5 mm is used, and trimming is not necessary.

2.1. Pass Band Filters

Filters covered in the report mentioned above [1, 2] were used as the band pass filters for the signal frequencies and the local oscillation frequencies. Filters with a construction such as that shown in Figure 1 were used in this converter; however, as was mentioned in the previous reports, they may have either a rectangular shape or an H shape. The frequencies are adjusted by adjusting either the diameters or the gaps of the circular parts.

The properties of the pass filters for local oscillation frequencies and signal frequencies are shown in Figure 2(a) and (b). The signal frequency pass filter has a center frequency of 12 GHz, an insertion loss of 0.3 dB, and a 3 dB down band width of 230 MHz. It imparts an attenuation of 30 dB or more in the



(a) Characteristics of local oscillation pass filter

(b) Characteristics of signal pass filter

Figure 2. Pass band filter

local oscillation frequency and the image frequency. The local oscillation frequency pass filter has a center frequency of 11.58 GHz, an insertion loss of 1.2 dB, and a 3 dB or less band width of 140 MHz. It displays an attenuation of 30 dB or more in the signal frequency and the image frequency. Its band is somewhat narrower than that of the signal frequency pass filter in order to prevent leakage with respect to the signal frequency. Consequently, there is a slight increase in the insertion loss.

The unloaded Q for one of the filters used in the two pass filters is about 1,500 - 2,000. /3

2.2. Schottky Diode Mount

The mounting circuit of the Schottky diode is shown in Figure 3(a). A beam lead diode or a Schottky diode for microwave integrated circuits is used as the diode. The diode can be mounted directly on the planar circuit.

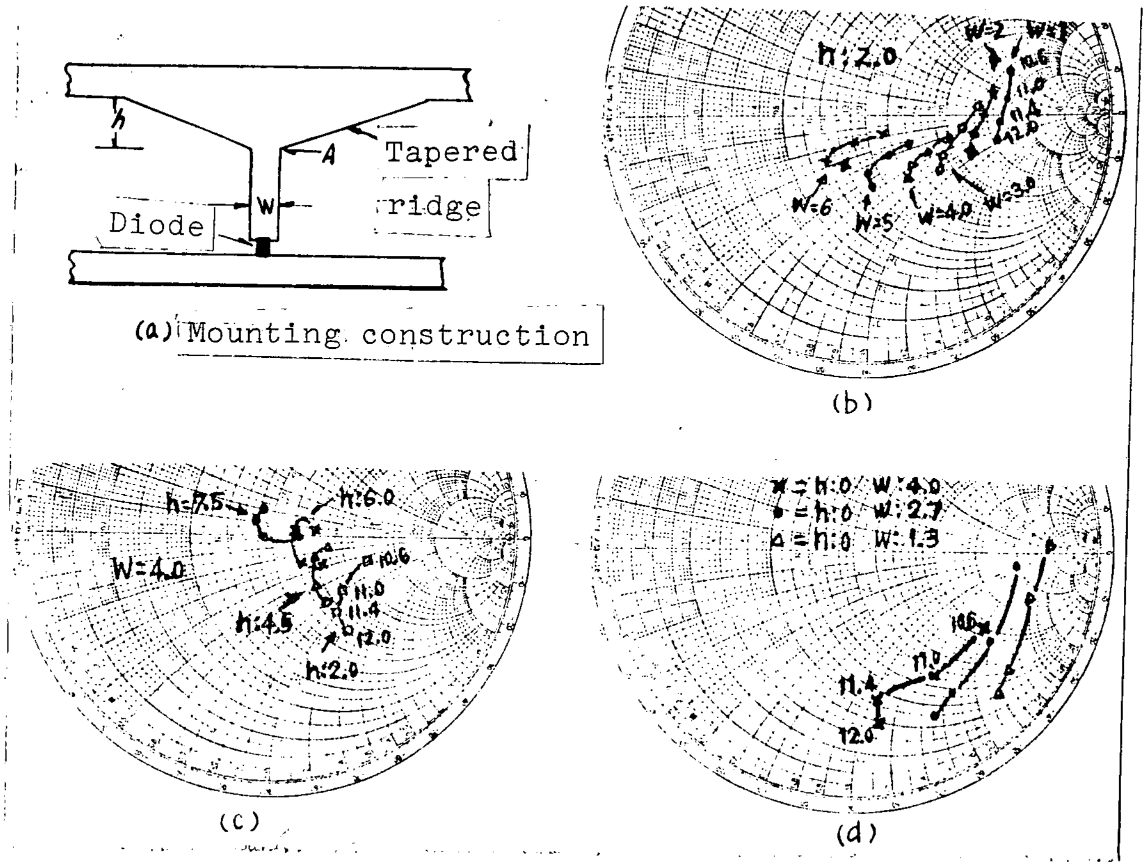


Figure 3. Relationship between diode mount and impedance

An important factor in determining the construction of the diode mount is to find a circuit which matches, over a broad band area, the diode impedance, which in actuality varies from tens to hundreds of ohms in accordance with the magnitude of the local oscillation exciting voltage. One might consider the round and flat posts (short-circuiting at the tip) which have been used in the past, or open-ended antennas which utilize the radiation effect of the antennas. However, when round posts or flat posts alone are used, the post length will be determined by the height of the waveguide, an excessive reactance will enter, and matching will become difficult on account of the compensation for this reactance. Consequently, the band width necessarily will become narrow. In this method of mounting the diode on the base of an open-ended antenna, utilizing the radiation effect of the antenna, it is possible to alter the antenna length in order to vary the impedance by about 50 to 200 ohms. The band width can also be widened by increasing the thickness of the antenna.

However, since it is desired to use a single metal plate in this converter, it will be necessary to support the diode and /4
the antenna if an open-ended antenna is used. Therefore, it was decided to adopt a construction in which the diode can be mounted directly using only the metal plate. As is shown in Figure 3(a), we used a construction consisting of a distributing line transformer and a tapered ridge part. The flat post located near the $\lambda/4$ line is connected with the tapered ridge erected vertically at the center of the H surface of the waveguide, and the diode is connected between the other H surface (bottom surface) and the flat post. In this case, the flat post inserted parallel to the E surface of the waveguide will function approximately as a transformer for the $\lambda/4$ distributing line. In other words, if the diode impedance is Z_D and the impedance of the $\lambda/4$ line is Z, the impedance towards the diode side at point A in Figure 3(a) will be Z^2/Z_D. Z can be freely varied by changing the width of the post. Therefore, impedance matching is possible even in diodes with a low impedance. However, in actual practice it is necessary to perform a theoretical analysis, rather than making such simple approximations. Therefore, experimental studies were made concerning the impedance.

Figures 3(b), (c), and (d) show the impedance curves seen from the terminal, where the diode is to be inserted when the width of the flat post W andnthe height of the tapered ridge h were varied. Figure 3(b) plots on a Smith chart the impedance changes resulting from changes of the flat post width W when the length of the flat post was $\lambda/4$ of 12 GHz, or 6.2 mm, and the value of h was 2.0 mm (using a WRJ-120 waveguide). The results indicated that the changes corresponded to the approximation described above. Figure 3(c) shows the impedance when the taper height h was varied, while keeping the W of the flat post constantly at 4 mm. Figure 3(d) shows the impedance when only a flat post was used (with the end short-circuited) and the width W was varied. It is clear that the reactance was greater than in Figure 3(b), and that the band width was narrower. If these charts are used to select suitable values of W and h, it is possible to realize any desired impedance over a fairly broad band area.

The intermediate frequencies and the D.C. lead are derived from the base of the diode.

2.3. Considerations of the Image Impedance

Considerations of the image impedance are necessary in order to minimize the conversion loss. If the signal and local oscillation frequency pass filters are located on both sides of the diode mounting, when the image frequency is of the TE mode, short circuiting will occur at a point somewhat on the inside (on the filter side) from the end of the filter. Consequently, it is possible to vary the impedance at the image frequencies viewed from both ends of the diodes by means of the length between both filters. If the space between the signal and the local oscillation filters is set at $n\lambda/2$ of the image frequency, it will be theoretically possible to put the image impedance into an open state. However, the positions of the signal and the local oscillation filters are adjusted in order to match the diode impedance by means of the signal and local oscillation filters, and therefore it is impossible to attain a filter space matching the image frequency by this alone. In cases when there is a great distance between the signal frequency and the image frequency, changes of the frequency will cause a departure from the open state. In order to realize an open state in the strict sense, one must perform a theoretical analysis of the diodes and find the distance between the two filters and the optimum mounting shape.

In the case covered by this report, the image impedance displays a certain amount of deviation from the open state. This was confirmed also from the filter distance, in which matching was attained by means of the signal and local oscillation frequencies.

2.4. Local Oscillation Circuit

A gun diode is used as the local oscillation source, and the construction described in 2.2 was used as the mount. One problem in gun diodes is the fact that fluctuations of the oscillation frequency occur with respect to the temperature. However, this difficulty can be solved by the compensation method which has been used in the past, or by the self-injection method. /5
At the present time, the fluctuations are suppressed to approximately 2 - 3 MHz ($-20 \sim +50°$ C) by making simple compensations. However, if it is necessary, it is also possible to adopt the self-injection method in planar circuits. It is desirable to study this point in the future.

3. Test Results of Prototype Converter

Let us describe the test results for prototype converters trial-manufactured by forming the circuit patterns for each of the parts mentioned above on a single metal plate in the manner shown in Figure 1.

Figure 4 shows the characteristics of the prototype converter at a signal frequency of 12 GHz, an intermediate frequency of 420 MHz, and a local oscillation output of 19 mW (max). It

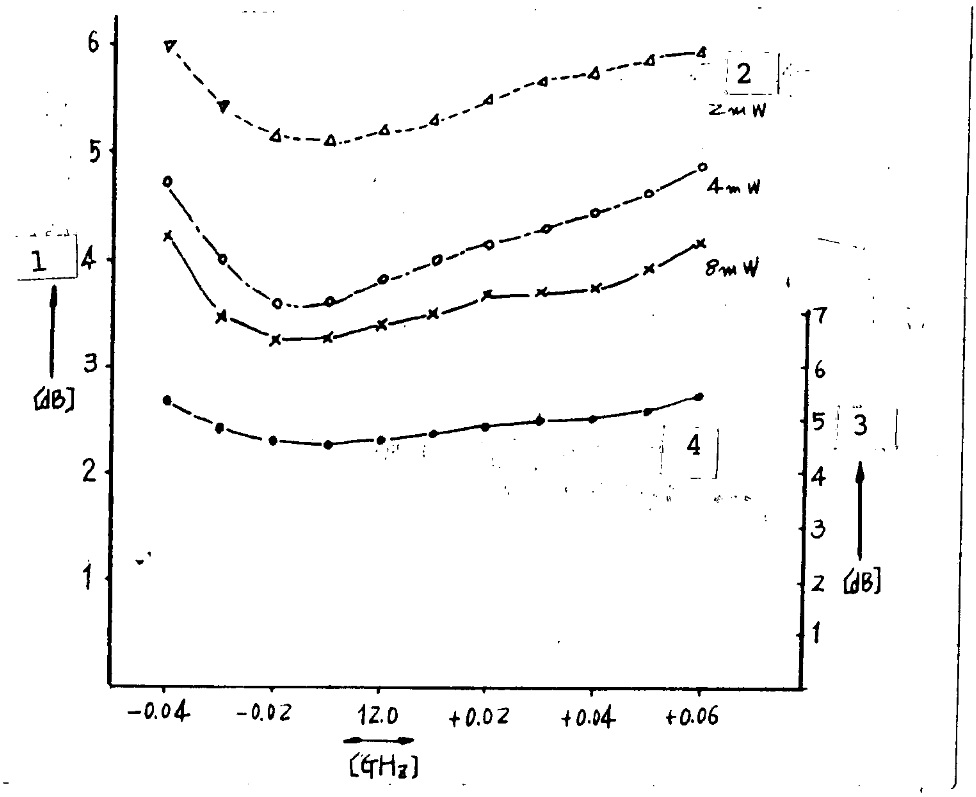


Figure 4. Characteristics of 12 GHz converter using mounted planar circuit:

1 — actual conversion loss, dB; 2 — local oscillation power; 3 — overall noise index; 4 — overall noise index (intermediate frequency amplifier NF approximately 2.0 dB)

was possible to obtain a minimum actual conversion loss of 3.2 dB. Connecting an intermediate amplifier with a noise index of approximately 2.0 dB, we performed measurements using liquid nitrogen as the noise source and obtained an overall noise index of 4.5 dB as a result. This value coincides with the calculating equation for the noise index during image impedance release, generally using the noise (diode current) produced in a Schottky diode as the shot noise.

4. Postscript

As described above, we trial-manufactured a converter which has a simple construction and which is capable of mass production. As topics for future study, we may mention analysis of the diode mount part and temperature stabilization of the gun diode.

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16. Abstract

A prototype low-noise converter was tested with a signal frequency of 12 GHz and intermediate frequency of 420 MHz. The results of a trial manufacture of the prototype are described.

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